

The Impact of the January 2022 Eruptions of Hunga Tonga-Hunga Ha'apai on Stratospheric Ozone in the NASA GEOS Earth System Model

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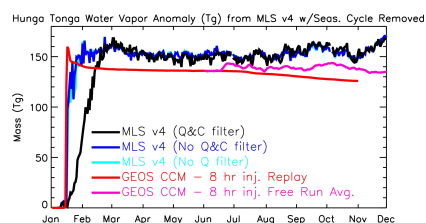
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Introduction

The January 2022 eruptions of the underwater Hunga Tonga-Hunga Ha'apai (HTHH) volcano injected about 150 Tg of water vapor (~10% of total stratospheric water) and approximately 0.5 Tg of sulfur dioxide into the stratosphere. Injected materials reached as high as ~55 km in altitude, while the main plume from the eruption travelled west over Australia and the Indian Ocean between about 20 – 30 km altitude.

MLS observations-derived H₂O abundance suggests that injected H₂O persists in the stratosphere with little removal.



What is the impact of HTHH eruption on stratospheric ozone in the next few years?

GEOSCCM Simulation

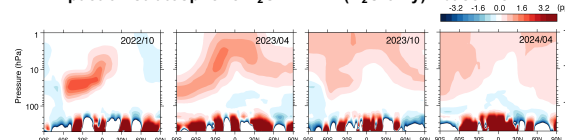
Three sets of 4-member ensemble simulations of the HTHH eruption were performed with the NASA Goddard Earth Observing System (GEOS) model with the full chemistry version (global ~100 km, 72 level, called **GEOS CCM**). The GEOS CCM simulations include the injection of water from the eruption. For aerosols, GEOSCCM used the GOCART aerosol module, which treats the chemical production of sulfate aerosol from the volcanically injected SO₂. These simulations were driven with the CMIP6 surface boundary conditions.

Three 4-member ensembles:

- **Baseline**: Control run with no volcanic emission
- **H₂O only**: Volcanic water injection
- **H₂O + SO₂**: Volcanic SO₂ and water injection

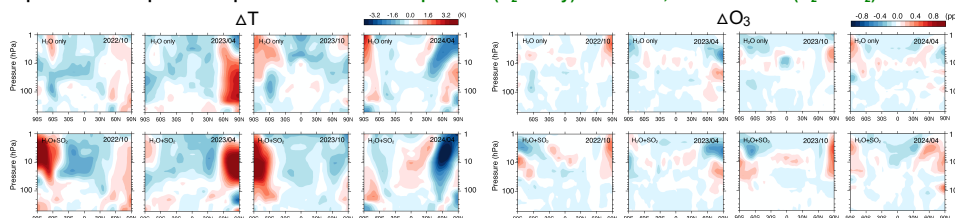
Evolution of Stratospheric H₂O, Temperature, and O₃ after Eruption

Impact on stratospheric H₂O: HTHH (H₂O only) - baseline



The majority of the HTHH injected H₂O was transported southward into the Antarctic at the end of 2022 with a second branch transported upward followed by poleward transport into both N.H. and S.H. in the following two years (2023-2024).

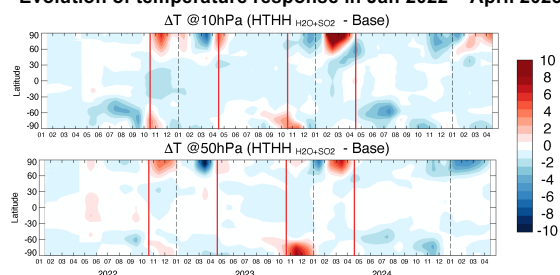
Impact on stratospheric temperature and ozone: top: HTHH (H₂O only) - baseline; bottom: HTHH (H₂O+SO₂) - baseline



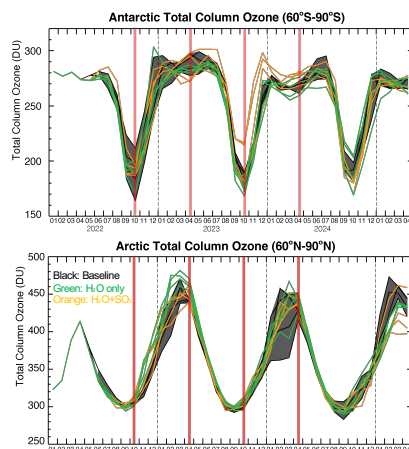
Patterns of the model simulated temperature and ozone responses to HTHH eruption are somewhat similar between the H₂O+SO₂ ensembles and the H₂O only ensembles, but the magnitudes are overall larger in the H₂O+SO₂ simulations than the H₂O only simulations.

GEOSCCM Simulated HTHH Impact on Stratospheric Ozone

Evolution of temperature response in Jan 2022 – April 2025



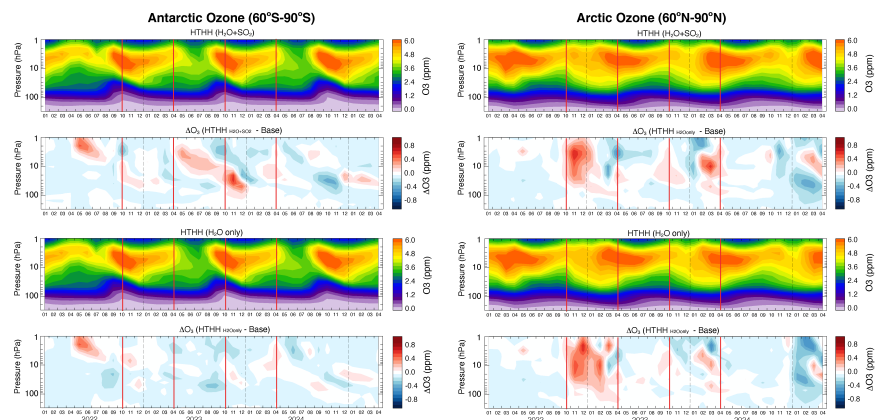
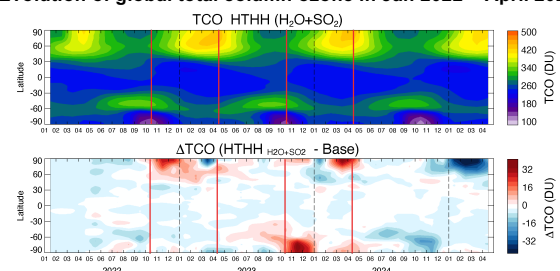
Impact of HTHH eruption on polar ozone



Future work:

- comparison and evaluation of model responses with satellite observations
- Understanding the chemical responses that are related to the polar ozone changes

Evolution of global total column ozone in Jan 2022 – April 2025



- The injection of HTHH water and SO₂ into the stratosphere has a long-lasting impact (a few years) on temperature and ozone, particularly in the polar stratosphere
- Simulated temperature and ozone responses are in general larger in the H₂O+SO₂ simulations than the H₂O only simulations
- Dynamical forced variability is large. Hence, isolating the HTHH signal is challenging, and more (>4) ensemble members are needed for better impact quantification.

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